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FOREST INSECT INVESTIGATIONS

WESTERN PINE BEETLE EMERGENCE AS AFFECTED BY LOW WINTER TEMPERATURES

Progress Report No. 2

By

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U. S. Bureau of Entomology

Portland, Oregon
February, 1934

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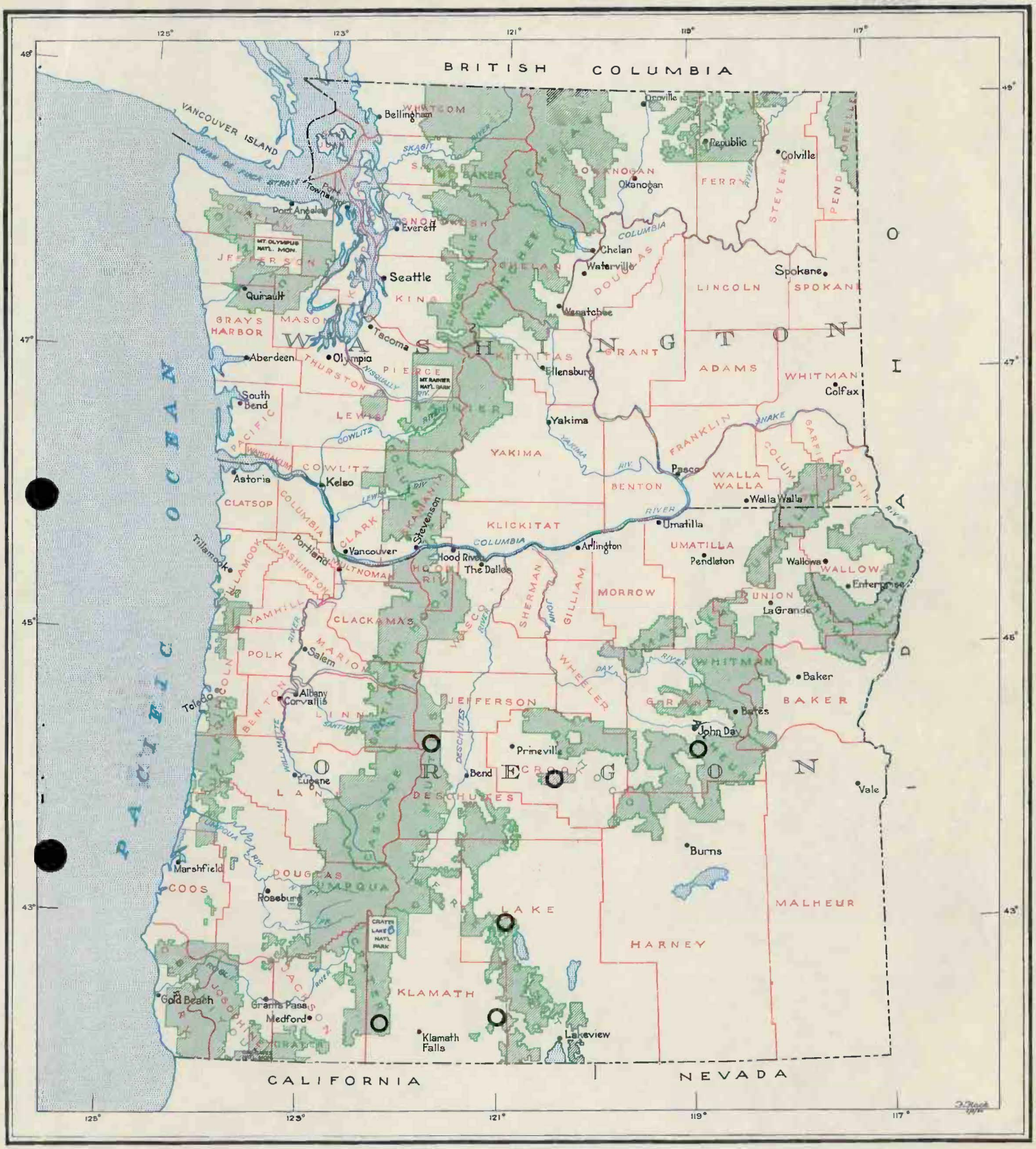

LEGEND

State Lines

National Forests

County boundaries

PACIFIC NORTHWEST FOREST EXPERIMENT STATION

Project

O Location of plots where emergence counts were made during 1933.

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WESTERN PINE BEETLE EMERGENCE AS AFFECTED

BY

LOW WINTER TEMPERATURES

Introduction

Heavy mortality of overwintering broods of the western pine beetle (Dendroctonus brevicomis Lee) in Oregon, Washington and California during a period of cold weather in December 1932 and again in February, 1933 emphasized the importance of low temperatures in reducing the numbers of this primary forest insect pest. Widespread destruction of a high percent of these beetles by cold resulted in the closing down of active control projects in both Oregon and California and in the instigation of a study to determine the general effect of the cold spell throughout the region affected. It was a co-operative study in which both the Berkeley and Portland Insect Field Stations participated. The study by the Portland station was divided into three parts:

(1) Brood analysis of bark samples sent in to the laboratory by forest officers from various parts of the region.
(2) Bark counts from these same areas following emergence of the beetles, to determine ultimate effect upon beetle populations.
(3) Surveys of forest areas following attacks to determine final effect upon epidemic trends.

Part one of the project covering brood analysis of bark samples was completed during the winter of 1932-33 and a comprehensive progress report prepared on this phase of the investigation. Part two on bark counts from some of the same areas following emergence of the beetles was carried on during the summer of 1933 and it is the information to date on this phase of the investigation which makes up the main body of this report. Part three on surveys of forest areas following attacks was completed during the summer and the data on them summarized in annual survey reports. Sufficient data, both from the work on brood analysis and that on the surveys, are included in this report so that close comparisons of the different ways in checking on the effect of the freeze can be made.

Personnel

The emergence counts were made chiefly with the assistance of men enrolled at the Civilian Conservation Corps camps. Small picked crews of three to five men were selected for this work on the areas covered and all work was done

under the immediate supervision of someone from the office of Forest Insects, either J. M. Whiteside, Field Assistant or the writer. In all, some twenty five men were used in the course of the work on emergence counts.

Most of the work on the annual forest insect surveys plots was done by W. J. Buckhorn, Scientific Aide and a CCC crew of five men. The remainder was done chiefly by Whiteside and a similar crew of assistants.

Areas Examined

Six of the areas from which infected bark had previously been collected and analyzed were selected as good working centers from which desireable information on beetle emergence could be obtained. They were chosen on the basis of the amount of winter kill as indicated by early bark analysis, on their proximity to CCC camps and according to their geographical distribution. The areas examined were as follows:-The Murderers Creek unit, on the Malheur National Forest; The Maury Mountain unit on the Ochoco National Forest; The Metolius unit on the Deschutes National Forest; The Cliff Springs unit, on the Fremont National Forest; The Clover Station unit, on the Rogue River National Forest, and the Ely unit on private lands in southern Oregon. (See map.) In addition to bark analysis and emergence counts from the above Oregon forest areas annual surveys of insect losses have been made on them in order to further supplement the information obtained on emergence counts.

Methods

After all summer emergence had taken place, the areas were visited and emergence counts made on a number of trees which had contained overwintering broods of the beetles. In this case, these were the 1932 late summer and winter trees. On three units additional emergence counts were made on a number of 1930 and 1931 winter trees in order to obtain data for a comparison of emergence following mild winters with that following more severe winters. In addition a few counts were also made on trees killed during other years.

In the past, there has been considerable discussion on the value of large quantities of data taken on the various events in the life history of the western pine beetles. In 1928 Keen (2), working on this insect, analyzed the brood statistics obtained over an eleven year period. He found little justification for the continuation of the general methods of random sampling which had been used previous to that time. Emergence counts for different years, different generations, different heights on the trees, different tree sizes, exposures and varying degrees of attack, showed "a tremendous variation, with a range from 0 to 340 beetles per square foot and with no central tendency or mode." It was therefore evident that in order to obtain more valuable data on emergence it would be necessary to restrict it to a very limited set of conditions. It was only after careful consideration of the results of previous methods of sampling that a uniform satisfactory system of sampling was developed. It proved to be accurate to within 10 percent or less and thus far has stood up under statistical analysis. Briefly, it consisted of the following:- (1) selection of trees in which the generation and year of attack was know; (2) selection of trees within a diameter range of 16 to 30 inches; (3) taking bark samples from the second

log only, usually from 15 to 25 feet above ground; (4) removal of samples in a band around the tree so as to include all sides; (5) use of only those samples which showed more or less normal attack of (Dendroctonus brevicomis Lec); (6) selection of bark of average thickness by eliminating both the very thin and the very thick bark. No attempt to count actual attack was made since the accuracy of such counts is at best questionable. While this method does not give a sampling of all the conditions under which the western pine beetles may breed, it does give a much better index to the variations in emergence counts when comparing one year with another.

Under the methods of bark counting previously used, a standard deviation of 30 was not unusual, with an average of about 65. To bring the error of this average within 10 percent or plus or minus 6 would require $n = \frac{(s)^2}{\bar{x}^2}$ or $\frac{30^2}{6^2}$ or 1250 square foot samples, which would involve a tremendous amount of bark counting. With the new method, the standard deviation was found to be 34 when the average was 116. To reduce this to an error of 10 percent or plus or minus 12 would require the counting of $n = \frac{(s)^2}{\bar{x}^2} = \frac{(34^2)}{12^2} = 289$ square feet. This number of samples is not an unreasonable number to obtain and was usually obtained under the "rule of thumb" method described below.

Enough counts on beetle emergence for an individual tree were made so that the addition of three more samples did not change the average more than ten percent. The same system was used to decide upon the number of trees necessary to represent each area. Usually from 15 to 20 samples was sufficient from each tree and likewise 15 to 20 trees proved to be ample for each area covered. Emergence holes were counted by the "tooth-pick method" earlier used by Wagner and others in California. It consists of filling all visible holes in the foot of bark to be sampled, with ordinary tooth picks. If they come through into the parent adult galleries the holes are designated as ventilation holes. If they go only part way through or are forced through the bark outside, the parent galleries, they are counted as emergence holes. By filling all holes and then removing the tooth picks from the ventilation holes the others designating the emergence holes can easily be removed and counted. Entrance holes, usually filled with pitch, seldom confuse the records. Where they have any effect at all they would at the most only slightly increase the count on ventilation holes. This method was some slower than merely counting the holes and marking them with colored pencil, however, it had the very great advantage of permitting careful check of the accuracy of the work being done.

The following form will serve to show how individual tree records were taken in the field. It is an actual record of emergence counts made on a 1932 winter tree on the Rogue River National Forest.

TABLE 1

Tree #6 | Diameter of tree 32" | 1932 W

Sample number	Ht. on tree	Side of tree	Bark thick.	Ventilation holes	Exit holes	Cum. total	Average
1	20-25'	N	1 1/8"-1½"	24	53	55	53
2	20-25'	S	1 1/8"-1½"	25	14	67	33
3	20-25'	N	1 1/8"-1½"	16	29	96	32
4	20-25'	W	1 1/8"-1½"	23	51	147	37
5	20-25'	S	1 1/8"-1½"	26	15	162	32
6	20-25'	E	1 1/8"-1½"	19	31	193	32
7	20-25'	W	1 1/8"-1½"	22	31	224	32
8	20-25'	S	1 1/8"-1½"	18	9	233	29
9	20-25'	N	1 1/8"-1½"	16	46	279	31
10	20-25'	E	1 1/8"-1½"	22	13	291	29
11	20-25'	S	1 1/8"-1½"	24	17	308	28
12	20-25'	E	1 1/8"-1½"	19	51	359	28
13	20-25'	N	1 1/8"-1½"	31	34	373	29
14	20-25'	W	1 1/8"-1½"	22	13	386	28
15	20-25'	E	1 1/8"-1½"	5	34	420	28
16	20-25'	W	1 1/8"-1½"	32	22	442	28
17	20-25'	E	1 1/8"-1½"	17	26	468	28
18	20-25'	N	1 1/8"-1½"	19	10	478	27

Plot cruises were made as in former yearsusing a three man crew, a compassman, and two spotters. The cruisers were also recruited from the CCC camps and in many cases the same crew handled both jobs.

Basis

The data summarized in the following report is based on the examination of 5115 square feet of bark taken from 210 trees on six different areas distributed throughout the ponderosa pine region of Oregon. Preliminary samples and discarded samples of 101 square feet of bark from 13 trees were also included in the examination but the data on them was not used. In addition some 57 ponderosa pine plots covering 16,000 acres in the same general areas were cruised for beetle losses and the summaries on these cruise data furnish a good basis for the conclusions which are presented in the following report, especially on the final effect of low winter temperatures in destroying bark beetle broods.

Data

Normal emergence

Normal or average emergence for the western pine beetle was determined by Keen (2) as 65 per square foot. This average was secured through emergence counts on ponderosa pine bark representing a wide range of conditions over a period of eleven years. It included bark counts both during favorable and unfavorable years, during increasing epidemics and under endemic conditions. It also covered all generations alike, including two summer and one winter generation as well as other overlapping generations. Furthermore it included counts from all sizes of trees, all heights and exposures on the trees and from all bark thicknesses. It is apparent then that 65 represents a general average emergence after all other factors have taken their toll.

To determine the effect of the freeze on subsequent emergence, it seemed advisable to exclude as many of the above variables as possible and thus obtain a relative figure for emergence during mild winters for comparison with emergence following more severe winters. It is true that such a figure represents the average emergence only under optimum conditions however, it serves as a fairly accurate basis for comparative emergence following cold years and thus reflects the effect of low winter temperatures. The winter 1930 and 1931 were termed mild because sub-zero temperatures were not experienced during either of them. A series of emergence counts was made on 1930 winter trees from the Klamath and Bly areas and on the 1931 winter trees from the Metolius area (few 1930 trees had previously been spotted on this area.) The data are summarized by individual trees from the three areas and are presented in the following tables II, III, and IV, respectively. The same data is also graphically presented in graph I at the end of this report. Table II shows the western pine beetle emergence from ponderosa pine trees of the 1931 winter generation on the Metolius area of the Deschutes National Forest.

Emergence of Western Pine Beetle in Ponderosa Pine

1951 Winter Trees

TABLE II

Deschutes N. F. Metolius Area

Tree No.	No. Sq.' Bark Samples	Ht on Tree	Tree Dia.	Bark Thick.	Ventilation Holes	Average Exit Holes Per Square Foot: Total Exit Holes Per Tree Sample	Cum. Samples	Per Sample	Cum. Average
1	20	20'	32"	4/8-1"	485	1438	1438	72	72
2	20	20'	22"	4/8-6/8"	335	1954	3392	98	85
3	19	20'	26"	7/8-1 4/8"	298	2464	5856	130	99
4	16	15'	40"	3/4-1"	401	1809	7665	113	102
5	14	25'	22"	5/8-1"	175	1015	8680	73	97
6	15	15'	36"	1 1/8-1 5/8	295	1654	10334	110	99
7	20	20'	28"	7/8-1"	575	3136	13470	156	108
8	18	25'	34"	1 1/8-1 4/8	296	2551	16021	142	113
9	15	20'	28"	5/8-6/8"	280	1769	17790	118	113
10	16	18'	30"	7/8-1 3/8	267	2486	20276	155	116
11	10	25'	24"	3/4-7/8"	114	984	21260	98	116
Totals 11	185				3518	21260			Average 116

Examination of the data presented in table II on beetle emergence from 1951 winter trees on the Metolius shows that from 185 square feet of bark taken from 11 trees, beetle emergence averaged 116 per square foot. The range in emergence from all samples was very great varying from 15 to 274 per square foot with a poorly defined central tendency between 70 and 130 (graph 1.) The standard deviation was 66 and the standard error 4.2. This is by far the greatest standard error obtained in all of the areas or years examined. However this figure indicates an accuracy of plus or minus 4, thus placing emergence between 112 and 120 per square foot.

Table III presents summarized data on western pine beetle emergence in ponderosa pine trees of the 1950 winter generation on the Clover Stem on area of the Rogue River National Forest.

Emergence of Western Pine Beetle in Ponderosa Pine

1930 W Trees

Table III

Rogue River National Forest-Clover Station Area

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Samples	Average Exit Holes Per Square Foot Cum. Average
1	20	20'	44"	7/8-1½"	331	1429	1429	71	71
2	17	20'	30"	1/2-7/8"	455	1783	3212	105	87
3	14	20'	30"	6/8-1"	250	1542	4754	110	94
4	15	25'	28"	6/8-1"	308	1626	6380	109	97
5	15	20'	28"	1-1½"	197	1728	8108	115	100
6	17	20'	40"	1-1 3/8"	181	1706	9814	100	100
7	15	20'	44"	1-1½"	159	1850	11664	123	103
8	17	20'	26"	4/8-7/8"	356	1512	13176	89	101
9	15	25'	24"	6/8-1"	309	1784	14960	119	103
10	15	20'	26"	5/8-1"	225	1621	16581	108	104
11	18	25'	25"	6/8-7/8"	332	1603	18184	90	102
12	18	20'	25"	3/4-1½"	194	2165	20547	120	104
Totals									Average
12	196				3257	20547			104

Briefly the above data in table III shows that in 196 square feet of bark from 12 trees, beetle emergence averaged 104 per square feet. The range in emergence from all samples was from 18 to 198 per square feet with a well defined central tendency between 100 and 110 (graph I.) The standard deviation was 54 and the standard error 2.4. This indicates that the average emergance of 104 is accurate to approximately a plus or minus 2 and falls between 102 and 106.

Table IV presents summarized data on western pine beetle emergence in ponderosa pine trees of the 1930 winter generation in the Bly area on private lands in southern Oregon.

Emergence of Western Pine Beetle in Ponderosa Pine

1930 V Trees

TABLE IV

PRIVATE LANDS--BLY AREA

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Samples	Average Exit Holes Per Square Foot Cum. Average
1	19	25'	32"	1/2-7/8"	414	1911	1911	100	100
2	14	15'	20"	5/8-7/8"	253	770	2681	55	81
3	15	15'	26"	1-1 1/8"	234	1673	4354	129	95
4	14	15'	20"	1 3/8-2"	163	1628	5982	116	100
5	14	20'	20"	3/4-1"	318	1863	7845	133	106
6	14	20'	30"	1-1 1/2"	139	1923	9768	137	111
7	14	20'	30"	3/4-1"	215	1834	11602	131	114
8	14	15'	44"	6/8-1"	177	1651	13253	119	114
9	14	20'	24"	6/8-1 1/8"	210	1727	14980	123	115
10	14	20'	32"	7/8-1 1/4"	137	1524	16504	109	115
11	14	20'	26"	5/4-1 3/4"	157	1634	18058	110	114
12	14	20'	28"	1-1 1/4"	112	1577	19415	98	113
13	14	20'	22"	7/8-1 1/4"	96	2215	21630	157	116
14	14	20'	22"	6/8-1 1/8"	194	1621	23251	116	116
Total 14	200				2849	25251			Average: 116

Data from the above table (IV) shows that in 200 square feet of bark from 14 trees, beetle emergence was 116 per square foot. The range in emergence from all samples was from 23 to 274 with a well defined mode between 110 and 120. The standard deviation was 54 and the standard error 2.4. As in the preceding case, the degree of accuracy is within plus or minus 2 placing emergence between 114 and 118.

These emergence counts (tables 2, 3, and 4 inclusive) while not strictly comparable, coming as they do from different areas and for different years, give a fair indication of what emergence may be expected during the years when no subzero temperatures occur. They show averages of 116, 104 and 114 per square foot respectively or a total average of 112. This figure is used throughout this report to represent normal emergence. It is the basis used for figuring percent of reduction in beetle emergence during abnormally cold years.

Emergence Following The Freeze

Malheur National Forest

The data on the Malheur National Forest was collected on the Murderer's Creek unit and the results on the 19 trees which were sampled are presented in table V.

Emergence of Western Pine Beetle in Ponderosa Pine

1932 W Trees

TABLE V

Malheur National Forest

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Sample	Average Exit Holes Per Square Foot Cum. Average
1	14	20'	20"	4/8-5/8"	471	112	112	8	8
2	20	20'	30"	6/8-1 1/4"	205	86	198	4	6
3	15	15'	28"	1 2/8-1 5/8"	208	187	385	12	8
4	14	15'	18"	6/8-7/8"	242	73	458	5	7
5	17	20'	26"	6/8-1"	272	52	510	3	6
6	12	30'	38"	6/8-1"	265	41	551	3	6
7	18	30'	44"	1-1 5/8"	324	106	657	6	6
8	16	15'	26"	7/8-1 3/8"	122	21	678	1	5
9	16	20'	26"	6/8-1 1/8"	184	5	683	0	5
10	14	10'	22"	1-1 3/4"	191	33	716	2	5
11	15	10'	24"	1-1 3/8"	176	15	731	1	4
12	15	10'	28"	7/8-1 3/4"	259	29	760	2	4
13	17	10'	22"	6/8-2 1/8"	177	43	803	3	4
14	13	10'	20"	6/8-1"	116	5	808	0	4
15	15	15'	24"	7/8-1 1/8"	260	13	821	1	4
16	14	10'	20"	7/8-1 1/8"	200	26	847	2	3
17	12	10'	24"	7/8-1"	107	14	861	1	3
18	12	10'	22"	6/8-1 2/8"	111	6	867	0	3
19	15	20'	30"	6/8-1 3/8"	278	23	890	2	3
Totals 19					4146	890			Average: 3

Loss in beetle population due to too low winter temperatures* -97%

(*Figured on the basis of a normal emergence of 112 per square foot.)

It can be seen from the above table (V) that very few pine beetles on this area survived the severe cold of 1932-33 and lived to emerge successfully. An average beetle emergence of only 3 per square foot was obtained from the above examinations. The range in emergence was from 0 to 25 with a mode between 5 and 10. The standard deviation was 4.5 and the standard error .25. This figure indicates that the emergence of 3 is accurate to plus or minus .25, that is, it probably does not vary more than from 2.75 to 3.25 per square foot. This emergence shows a reduction of 97 percent below normal emergence. In comparison with this reduction, it is pertinent that we examine at this point the figures previously obtained on brood analysis and also the figures on subsequent reinfestation.

Brood analysis of 147 square feet of bark examined last winter from five areas on the Malheur Forest gave 8990 living larvae and 21,960 dead larvae with an average mortality at that time of 85 percent. For more detailed information on brood mortality on these areas the reader is referred to Progress Report Number I, prepared in 1933 at the Portland Station (1).

Subsequent fall cruises on four 160 acre plots on the Malheur Forest showed that during 1932 preceeding the freeze beetle losses consisted of 626 trees with a volume of 268,110 board feet but that during 1933, the year following the freeze, these losses decreased to 181 trees with a volume of 123,700 board feet, a decrease of 57 percent in infestation. More complete information on these cruises can be obtained by referring to the 1933 annual reports on barkbeetle surveys (3).

Ochoco National Forest

Similar data on beetle emergence on the Ochoco National Forest was secured from the Emery Mountain unit and is summarized in the following table VI.

Emergence of Western Pine Beetle in Ponderosa Pine

1932 W Trees

TABLE VI

Ochoco National Forest-Maury Mt. Unit

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Sample	Average Exit Holes Per Square Foot Cum. Average
1	19	20'	32"	5/8-7/8"	452	540	540	28	28
2	18	15'	28"	1-1 5/8"	298	565	1105	31	30
3	14	20'	32"	7/8-1 1/8"	315	333	1438	24	28
4	17	20'	32"	7/8-1 6/8"	205	558	1996	33	29
5	20	20'	30"	1-1 1/2"	291	588	2584	29	29
6	12	15'	24"	1 1/8-2 1/4"	119	239	2823	20	28
7	14	20'	28"	5/8-1"	252	191	3014	14	27
8	14	20'	26"	1-1 1/8"	112	259	3273	18	26
9	15	20'	28"	1-1 6/8"	40	77	3350	5	25
10	14	20'	28"	1 4/8-1 7/8"	220	373	3723	27	24
11	14	20'	36"	1 2/8-1 7/8"	261	350	4073	25	24
12	16	20'	29"	1/2-1"	317	411	4484	26	24
13	15	20'	24"	1/2-1"	372	273	4757	18	24
14	15	20'	28"	3/4-1"	377	381	5138	25	25
15	15	20'	30"	7/8-1 2/8"	184	119	5257	8	23
16	15	20'	24"	6/8-1 1/8"	193	208	5465	14	22
17	15	15'	24"	1/2-1"	321	87	5552	6	21
18	16	15'	28"	1-1"	75	129	5681	8	20
19	20	15'	30"	6/8-1 1/8"	265	234	5915	12	20
20	20	15'	38"	1 1/2-1 5/8"	363	740	6655	37	21
Totals 20	318				5431	6655		Emergence	21
Loss in beetle population due to low winter temperatures									-81%

Considerably better insect survival and emergence occurred on the Ochoco Forest than that found on the Malheur. On the Maury Mountain unit the examination of 318 square feet of bark from 20 different trees gave an average emergence, based on the number of emergence holes, of 21 beetles per square foot. The range in emergence was from 0 to 91 with a mode between 10 and 20. The standard deviation was 15.6 and the standard error .87 indicating an accuracy in the average emergence of plus or minus .87 and therefore placing it between 20.13 and 21.87. This shows a reduction of 81 percent below the average emergence following mild winters. Here as on the Malheur area this is a greater reduction than either that found through brood analysis and through annual surveys.

Brood analysis of 276 square feet of bark from the Ochoco Forest during the past winter gave a total of 22,919 living larvae of the western pine beetle as against 25,766 dead, indicating a winter brood mortality of 57 percent (1).

Subsequent fall cruises (4) covering 8,969 acres on quarter section, half section and section plots showed the 1932 losses on these areas to be 7887 trees with a volume of 4,851,015 board feet as against 2683 trees with 1,925,650 board feet in 1933 or a decrease in 1933 of 60 percent.

Deschutes National Forest

The results of the examinations of emergence from 1932 winter trees on the Metolius area of the Deschutes National Forest are summarized in table VII

Emergence Western Pine Beetle in Ponderosa Pine

1932 W Trees

TABLE VII

Deschutes National Forest

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Sample	Average Exit Holes Per Square Foot Cum. Average
1	13	25'	28"	5/4-7/8"	320	166	166	13	13
2	20	25'	34"	7/8"	421	963	1129	48	34
3	16	20'	30"	7/8"	481	546	1675	30	33
4	13	20'	34"	5/8-1"	595	151	1826	12	28
5	18	20'	26"	5/8"	374	170	1996	9	24
6	16	20'	34"	1-1½"	511	382	2378	24	24
7	18	25'	34"	1	456	574	2952	32	25
8	12	30'	32"	3/4-1 1/4"	543	181	3133	15	24
9	14	20'	36"	5/8-7/8"	426	814	3947	58	28
10	20	20'	40"	1-1 1/2"	512	803	4750	40	29
11	18	20'	28"	1 1/8-1½"	290	874	5624	49	31
12	19	35'	22"	7/8-1 1/8"	249	418	6042	22	30
13	20	30'	22"	5/8-7/8"	288	166	6208	8	28
14	20	20'	28"	7/8-1"	415	809	7017	40	29
Totals									Average
W14	239				5281	7011			29

Loss in beetle population due to low winter temperatures -74%

On the Metolius area an average spring emergence from the 1932 winter trees of 29 beetles per square foot was found. The range in emergence was from 0 to 104 with a mode between 10 and 20. The standard deviation was 26.4 and the standard error 1.7. This indicates an accuracy of plus or minus 1.7 and places emergence between 27.3 and 30.7. This is the heaviest emergence obtained from any of the overwintering trees on any of the areas examined. When compared with a normal emergence of 112 per square foot it shows a reduction of 74 percent. Here again this figure is above less figures secured through other methods. It should be mentioned here that preliminary sampling on 1929 winter trees also gave a low average emergence of 25 beetles per square foot following an abnormally cold winter.

The 1932 and 1931 emergence from winter trees on this area is compared in graph II. It illustrates the difference between emergence following cold winters and that following more mild winters.

Brood analysis of 82 square feet of bark from the above area during the past winter gave a total of 7,596 living larvae and 7,704 dead larvae, or a mortality of 54 percent in the overwintering brood (1).

The fall cruises (5) on 1600 acres of ponderosa pine forest land showed the 1932 losses to be 421 trees with a volume of 322,625 board feet as against the 1933 loss of 192 trees and 249,000 board feet volume. This is a reduction of only 23 percent, the lowest found on any of the areas cruised.

In addition to the sampling of winter brood trees some further sampling on the Metolius area was done on those of the summer broods in order to obtain information on emergence from these types of trees. The first group examined was the 1932, B-2 trees. These are the second summer brood trees in which most of the insects overwinter as mature larvae although considerable fall emergence sometimes occurs on the south side of the trees or during extended warm fall weather. The results of the examinations of some 1932, B-2 trees on the Metolius area of the Deschutes National Forest are summarized in table VIII.

Emergence of Western Pine Beetles in Ponderosa Pine

1932 B-2 Trees

TABLE VIII

Deschutes National Forest

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Sample	Average Exit Holes Per Square Foot Cum. Average
1	15	20'	34"	3/4-1"	290	1463	1463	98	98
2	16	15'	20"	5/8-1	223	1026	2489	64	80
3	17	20'	20"	5/8-7/8"	130	586	3075	34	64
4	15	25'	22"	1/2-1"	238	252	3327	19	54
5	14	15'	20"	1/2-1 1/8"	195	546	3873	39	52
6	15	20'	24"	5/8-1 1/8"	157	217	4090	14	45
7	16	15'	28"	1/2-1 1/4"	366	777	4867	49	46
8	20	25'	38"	3/4-1"	300	911	5778	46	46
9	17	20'	32"	5/8-7/8"	344	719	6497	42	45
10	16	25'	32"	1-1 1/2"	215	2304	8801	144	55
11	15	35'	40"	1 3/8-1 1/2	292	1052	9853	70	57
12	15	25'	20"	1/2-1 1/8"	158	857	10710	57	57
13	20	20'	36"	7/8-1 5/8"	333	2115	12825	106	61
14	17	25'	20"	7/8-1"	414	486	13311	29	59
15	20	20'	22"	3/4-7/8"	460	249	13560	12	55
16	17	20'	22"	3/4-1 1/2"	166	1367	14927	80	57
17	16	25'	22"	5/8-3/4"	454	52	14979	3	54
18	15	35'	32"	1-1 1/2"	351	924	15903	62	54
19	15	25'	30"	7/8-1 1/4"	259	1191	17094	79	55
Totals									Average:
19	309				5343	17094			55

Table VIII is a summary of the data taken on 309 square feet of bark from 19 trees of the 1932 second summer generation on the Metolius area of the Deschutes National Forest. From these trees an average emergence of 55 per square foot occurred. This shows an average decrease in emergence of 51 percent below normal emergence. It will be remembered that an emergence of only 29 per square foot was obtained from the 1932 winter trees on this area. The difference in emergence then between these two types of trees is 26 per square foot or 93 percent more emergence from the B-2 trees than from the winter trees on the same area. This difference is most logically attributed to previous fall emergence before the cold weather occurred.

Another series of trees examined on the Metolius area was composed only of 1932 first summer generation trees. These are the trees which are attacked early in the summer and from which all emergence is usually completed during the summer months of the year of attack. The results of the examination of some 1932 B-1 trees on the Metolius area of the Deschutes National Forest are summarized in table IX.

Emergence of Western Pine Beetles in Ponderosa Pine

1932-B-1 Trees

TABLE IX

Deschutes National Forest

Tree No.	No. Sq. Samples	Ht on Tree	Tree Dia.	Bark Thick.	Total Exit Holes: Vent Holes	Per Tree	Cum. Samples	Average Exit Holes Per Square Foot: Per Sample	Cum. Average
1	16	20'	30"	5/8-5/8"	718	1737	1737	108	108
2	18	20'	22"	5/8-7/8"	372	1209	2946	67	87
3	15	20'	32"	6/8-1 1/8"	513	910	3856	60	79
4	20	25'	29"	1 1/2"	156	420	4276	21	62
5	18	20'	18"	6/8-1"	324	374	4650	20	55
6	20	25'	20"	5/8-3/4"	244	669	5319	33	50
7	18	25'	22"	5/8-3/4"	331	482	5801	27	46
8	20	20'	19"	1/2-3/4"	362	347	6148	17	43
9	20	20'	24"	5/8-3/4"	311	427	6575	21	43
10	18	15'	32"	7/8-1"	457	662	7237	37	44
11	13	15'	26"		393	455	7692	35	42
12	20	15'	22"	5/8-7/8"	154	454	8146	23	42
13	15	17'	32"	1 1/8-1 1/2"	135	392	8538	26	40
14	16	25'	18"	1/4-3/4"	286	318	8856	20	38
15	20	25'	28"	1-1 3/4"	194	639	9495	32	38
16	17	25'	24"	1/2-3/4"	498	1235	10730	75	38
17	16	25'	18"	1/2-5/8"	294	1064	11794	67	39
18	16	25'	16"	5/8-6/8"	313	722	12516	45	40
19	17	25'	30"	7/8-1 1/2"	358	946	13462	56	40
20	15	25'	28"	1/2-1"	625	1411	14873	94	43
21	16	25'	24"	5/8-1"	494	1464	16337	89	45
22	16	25'	22"	1/2-7/8"	404	1855	18192	116	48
23	14	40'	26"	5/8-7/8"	488	1307	19499	93	49
24	13	55'	29"	1/2-6/8"	535	1551	21050	119	52
25	15	30'	24"	5/8-1"	286	1338	22388	89	53
26	13	30'	30"	7/8-1"	321	1356	23744	104	56
27	14	35'	28"	7/8-1 1/2"	356	982	24726	70	56
Totals	442								Average 55

Emergence from 449 square feet of bark from 27 individual trees of the first summer generation averaged only 55 per square foot. In many cases in this series of examinations it was apparent that heavy work by Cerambycid larvae had materially affected the western pine beetle broods. Earlier preliminary examinations on the same area indicated a higher average summer emergence for other years. Only 20 feet of bark from a 1930 summer tree showed an average emergence of 147 per square foot while 60 feet sampled from three 1931 summer trees gave an average emergence of 101 per square foot. The low summer emergence for 1932 cannot be fully explained at this time. There is the possibility that there is a real difference between emergence from summer generation and overwintering brood trees.

Fremont National Forest

Data secured from the Cliff Springs unit of the Fremont National Forest regarding the severity of winter kill showed the insects on this area to have been affected almost as seriously as were those on the Malheur Forest. Table X summarizes the information on the Fremont Forest.

Emergence of Western Pine Beetle in Ponderosa Pine

1932 W Trees

TABLE X

Fremont National Forest

Fall 1933

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent. Holes	Total Exit Holes Per Tree	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Sample	Average Exit Holes Per Square Foot Cum. Average
1	16	20'	24"	7/8-1 1/8"	269	114	114	7	7
2	16	15'	24"	7/8-1 1/4"	332	81	195	5	6
3	14	20'	22"	1-1 1/2"	224	62	257	4	5
4	13	18'	20"	6/8-1 1/4"	361	98	355	8	6
5	15	20'	36"	6/8-1 1/8"	428	93	448	6	6
6	15	20'	24"	3/4-1"	310	60	508	4	6
7	17	20'	26"	6/8-1"	311	60	568	4	5
8	16	20'	32"	6/8-1 1/4"	194	98	666	6	5
9	15	20'	36"	6/8-1 1/2"	102	80	746	5	5
10	15	20'	26"	5/8-1 1/8"	174	38	784	2	5
11	13	20'	24"	6/8-1 1/2"	267	91	875	7	5
12	17	20'	24"	6/8-1 1/2"	235	82	957	5	5
13	15	15'	18"	6/8-1"	91	15	972	1	5
14	14	20'	20"	1-1 1/2"	217	116	1088	8	5
15	13	16'	18"	7/8-1 1/2"	200	172	1260	13	6
16	13	16'	22"	1 1/4-1 3/4"	158	81	1341	6	6
17	16	20'	26"	1/2-7/8"	436	115	1454	7	6
18	14	20'	24"	1-1 1/4"	135	57	1511	4	6
19	15	20'	28"	6/8-1 1/4"	328	29	1540	2	5
20	14	20'	28"	4/8-1 1/8"	224	54	1594	4	5
Totals									Average:
20	296				4992	1594			5

Loss in beetle population due to low winter temperatures -68%

In the Cliff Springs area of the Fremont National Forest an average spring emergence of only five beetles per square foot was obtained. The range in emergence was from 0 to 24 with a mode between 0 and 10. The Standard deviation was 4.3 and the standard error .25. This shows the emergence figure of 5 to be accurate to plus or minus .25 and places emergence between 4.75 and 5.25 per square foot. This light emergence meant a loss in beetle population of 95 percent as a result of the low winter temperatures.

Earlier counts on brood mortality made on 67 square feet of bark having 4,574 living and 11,938 dead larvae placed the average loss in brood at 81 percent (1).

Fall cruises in the same region (6) on four 320 acre plots showed the 1932 losses to be 538 trees with 215,120 board feet with a reduction in 1933 to 125 trees with 109,014 board feet, a reduction in volume of timber losses of 61 percent.

Rogue River National Forest

A count of western pine beetle emergence following the 1932-33 freeze was also made on the Clover Station area of the Rogue River National Forest. The results of this work are summarized in table XI.

Emergence of Western Pine Beetle in Ponderosa Pine

1932 Winter Trees

TABLE XI

Klamath Circle-Rogue River National Forest

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Total Exit Holes: Vent Holes	Per Tree Sample	Cum. Samples	Average Exit Holes Per Square Foot: Per Sample	Cum. Average
1	16	20'	24"	5/8-1 5/8"	532	326	326	20	20
2	14	10'	18"	7/8-1 2/8"	261	284	610	20	20
3	12	30'	26"	1 1/8-1½"	176	289	899	24	21
4	15	20'	30"	6/8-1 1/8"	353	531	1230	22	22
5	17	20'	32"	1-1⅛"	389	412	1642	24	22
6	18	20'	32"	1 1/8-1½"	380	478	2120	27	25
7	16	25'	20"	6/8-1 1/8"	259	247	2367	15	23
8	15	20'	20"	7/8-1 1/8"	269	197	2564	15	21
9	15	20'	30"	1-1 1/4"	274	290	2854	19	21
10	16	20'	28"	1-1 1/8"	516	348	3202	22	21
11	16	20'	18"	1-1½"	181	316	3518	20	21
12	18	20'	40"	1-1½"	564	394	3912	22	21
13	16	20'	22"	6/8-7/8"	329	322	4234	20	21
Totals									Average
13	204				3833	4234			21

Loss in beetle population due to low winter temperatures -81%

Emergence counts on 204 square feet of bark from 15 trees in the Clover Station unit of the Klamath Circle gave an average emergence of only 21 beetles per square foot. The range in emergence was from 0 to 55 with a mode between 10 and 20. The standard deviation was 12.6 and the standard error .88. Thus the emergence of 21 is accurate to plus or minus .88 and falls between 20.12 and 21.88. This is a reduction of 81 percent from normal emergence. The 1932 emergence from this unit is compared with that of 1930 in graph III. I shows the difference in emergence following cold and mild winters and also illustrates the 1932 reduction below the more normal 1930 emergence. This reduction is in all cases considerably greater than the less figures obtained through brood analysis and cruise records.

Brood analysis on only 31 square feet of bark showed 4,451 living larvae and 1,759 dead larvae or a winter brood mortality of only 33 percent (1).

More adequate data from fall surveys on this same general area showed that on 7 section plots the 1932 losses were 1,632 trees with 1,321,920 board feet volume and a reduction in 1933 to 656 trees and 667,000 board feet volume, an annual reduction in volume losses of 50 percent (7)

Bly Circle

Similar examinations were also made in the Bly District on private timber lands in southern Oregon and the results are summarized in table XII.

Emergence of Western Pine Beetle in Ponderosa Pine

1932 W Trees

TABLE XII

Bly District-Fall 1935

Tree No.	No. Sq.' Samples	Ht on Tree	Tree Dia.	Bark Thick.	Vent Holes	Total Exit Holes Per Tree Sample	Total Exit Holes Cum. Samples	Average Exit Holes Per Square Foot Per Sample	Average Exit Holes Per Square Foot Cum. Average
1	16	20'	34"	5/8-1 5/8"	303	270	270	17	17
2	14	20'	30"	6/8-1"	311	114	384	8	13
3	11	25'	26"	1 3/8-1 7/8"	102	134	518	12	13
4	13	20'	24"	6/8-1 1/8"	313	78	596	6	11
5	12	25'	26"	7/8-1"	253	97	693	8	11
6	14	15'	26"	3/4-1 2/8"	280	147	840	11	11
7	13	16'	22"	1-1 5/8"	98	128	968	10	10
8	16	15'	18"	1-1 3/4"	190	154	1122	10	10
9	12	20'	20"	3/4-1"	103	79	1201	7	10
10	21	25'	36"	1-1¼"	418	540	1741	26	12
11	14	20'	30"	5/8-6/8"	376	61	1802	4	12
12	13	25'	34"	7/8-1 3/8"	291	187	1989	14	12
13	14	25'	24"	3/4-7/8"	381	146	2135	10	12
14	14	30'	28"	5/8-1"	197	64	2199	5	11
Totals									Average
14	197				3616	2199	2199		11

Loss in beetle population due to low winter temperatures -90%

The 197 square feet of bark surface examined in the Bly region showed an average emergence of only 11 beetles per square foot. The range in emergence was from 0 to 54 with a mode between 0 and 10. The standard deviation was 11.8 and the standard error .84. Therefore an emergence of 11 is accurate to plus or minus .84 and thus falls between 10.16 and 11.84. It is compared with that of 1930 in graph IV. A winter mortality of 90 percent is indicated by these emergence data. This figure although some higher than the one obtained through earlier brood analysis or the one secured through subsequent cruises is reasonably close to both of them.

Brood analysis of 110 square feet of bark from the same region during the past winter showed that in this material there were 4801 living larvae and 15,842 dead. This was a decrease of 83 percent in overwintering broods as a result of the low winter temperatures which prevailed in the region (1).

In this unit the fall cruises on seven section plots of timber showed the 1932 loss to be 4360 trees with a volume of 3,154,695 board feet and the 1933 loss of 957 trees or 783,500 board feet, a reduction in volume loss of 75 percent (7).

Discussion

In order that data collected on winter brood mortality, as well as that on final emergence and that on infestation may be more readily compared, for purposes of discussion, the percent reduction in each case is shown in the following table (XIII).

Effect of Low Temperatures

On

The Western Pine Beetle by Areas

TABLE XIII

Forest Basis	Mortality of Overwintering Larvae: Per Sq. Ft.: Living	Dead	Weighted Percent	Bark Counts: Normal Emerg	Aver. Emerg. 1933	Reduction from Normal	Volume Timber Losses: Year	Board Feet	% Reduction
Malheur N. F.	61	149	183	112	26	97	1932: 1933:	288,110 123,700	57
Ochoco N. F.	85	95	57	112	21	81	1932: 1933:	4,851,015 1,923,050	60
Deschutes N. F.	92	94	54	112	29	74	1932: 1933:	322,625 249,000	23
Fremont N. F.	65	178	81	112	5	95	1932: 1933:	215,120 109,014	61
Rogue River N.F.: Klamath Circle	143	57	33	112	21	81	1932: 1933:	1,321,800 657,000	50
Private Land Bly District	44	124	85	112	11	90	1932: 1933:	3,154,695 783,500	75

Summarized data on three phases of the study on the effect of winter freezes on the western pine beetles are presented above for six eastern Oregon areas. They include for each area, the mortility in overwintering broods, the reduction in final emergence, and the reduction in infestation. It is evident from an examination of all the data thus far obtained on the effect of the 1932-33 freeze on the western pine beetle that it took a heavy toll among the insects exposed to it. Early examinations of the percent of winter brood mortality showed this figure to range from as high as 85 percent for some areas to as low as 33 for another. The percent of mortality appeared to

depend directly upon the degree of cold reached in the area.

In all cases the percent reduction in final emergence was found to be greater than that indicated by earlier brood counts. This subsequent increase in mortality is most logically attributed to the continued dying of the remaining brood due to the effect of the freeze, greater concentration of parasites, predators and other natural enemies, and the effect of disease and other factors taking their so-called normal toll. Also the possibility of errors in the methods of sampling must not be overlooked and these will be discussed at this point.

There is much evidence to show that the number of emergence holes in a particular area of bark is not the same as the number of beetles which came from that bark. There is reason to believe however, that the number of emergence holes, while not accurately representing the number of beetles, is a fair indicator of what emergence has taken place. In most cases it has been found that more beetles emerge from tested bark areas than are indicated by the emergence holes. Both Furniss, at the Berkeley Station and Buckhorn, at the Portland Station, in caging experiments with the western pine beetle have found wide differences in the number of beetles and the number of holes. Apparently, the heavier the broods, the more likelihood there is of two or more of the emerging beetles coming out of the same hole.

It seems reasonable to suppose that with a very limited number of beetles coming from the bark, such as was the case following the severe freeze, the number of emergence holes would be a far more accurate indicator of actual emergence than where emergence was comparatively heavy. Thus it is believed that the data collected from 1932 winter trees more nearly represents actual emergence than that obtained from either the summer trees or from the 1930 or 1931 winter trees where emergence was much heavier. More information is badly needed on this point and caging experiments for next summer are being planned to help clear up this matter.

The infestation on the areas cruised during 1932 and 1933 showed reductions varying from 25 to 75 percent. In general the greatest percent reductions occurred in the heaviest epidemic areas. Lesser reductions were found where endemic infestations occurred. These reductions did not follow temperatures as closely as did the earlier losses in overwintering broods. At first glance it would appear that the reductions in infestation are not in very close agreement with brood losses or with reductions in emergence. This may be partially explained by the fact that losses through infestation are computed on a yearly basis covering three generations of beetles while brood losses and reductions in emergence deal only with a single winter generation. Any building up of the infestation by the following summer broods would result in the attack of more trees and a corresponding decrease in the apparent effect of the previous winter freeze. Likewise any decrease in summer broods would increase the apparent effect of the freeze. Furthermore, we have no reason to believe that because we get a certain percent reduction in emergence we will necessarily get the same reduction in infestation. As shown by Keen (2) beetle population is not necessarily a good criterion of subsequent infestation. Too many other factors enter into the epidemiology of the western pine beetle and appear to outweigh the factor of population alone. Other possible factors, besides win-

ter kill, which may have had a bearing upon the reduced 1935 infestation are (1) improved tree growth conditions, (2) presence of more parasites and predators, (3) heavy concentration by birds, (4) effect of control operations in some areas. It is generally known that the improved moisture conditions of the past year or two are already being reflected in growth and apparent vigor of the ponderosa pine trees, and on this basis reduced infestations were predicted for 1935. Little is known regarding comparative abundance of insect and other natural enemies. Limited control operations were conducted on a very few of the areas examined and these were finally terminated by the effects of the freeze.

Summary

Emergence counts on over 3000 square feet of ponderosa pine bark have been made on six eastern Oregon areas in order to determine the effect of the low winter temperatures of 1932-33 on final emergence of broods of the western pine beetle.

In addition extensive loss surveys were made on the same areas for the purpose of determining the ultimate effect of the low winter temperatures on subsequent infestation.

The work was carried on chiefly with the assistance of men enrolled at the camps of the Civilian Conservation Corps.

The areas examined were located on the Malheur, Ochoco, Deschutes, Fremont and Rogue River National Forests, and on private lands in southern Oregon.

A normal emergence of 112 beetles per square foot, based on actual count of emergence holes, was found to occur following mild winters.

Emergence following the abnormally cold winter of 1932-33 was found to be far below normal emergence. It varied from 3 to 29 per square foot. Reductions ranged from 74 to 97 percent depending upon the degree of cold reached in the area.

Subsequent reinfestation, based on the difference in volume losses between 1932 and 1935, was reduced from 25 to 75 percent also depending upon the temperatures within the area and upon the degree of the infestation.

Limited data on emergence from summer generation trees indicated wider variations than those found in the case of winter trees only.

In some cases Cerambycids appeared to seriously interfere with western pine beetle brood development in summer generation trees. In others apparent fall emergence on some trees and on some parts of others greatly decreased the value of emergence data taken the following year.

While the freeze was very effective and widespread, its effect was found to be only temporary in nature. The quick return during the summer to near

epidemic conditions in some areas where overwintering broods had been extremely hard hit showed that the effect of the freeze did not extend beyond the emergence of the overwintering generation. This is reflected in the difference between beetle mortality and subsequent reinfestation on all areas examined.

Portland, Oregon
Feb 17, 1934

Respectfully submitted
J. A. Beal
Assistant Entomologist

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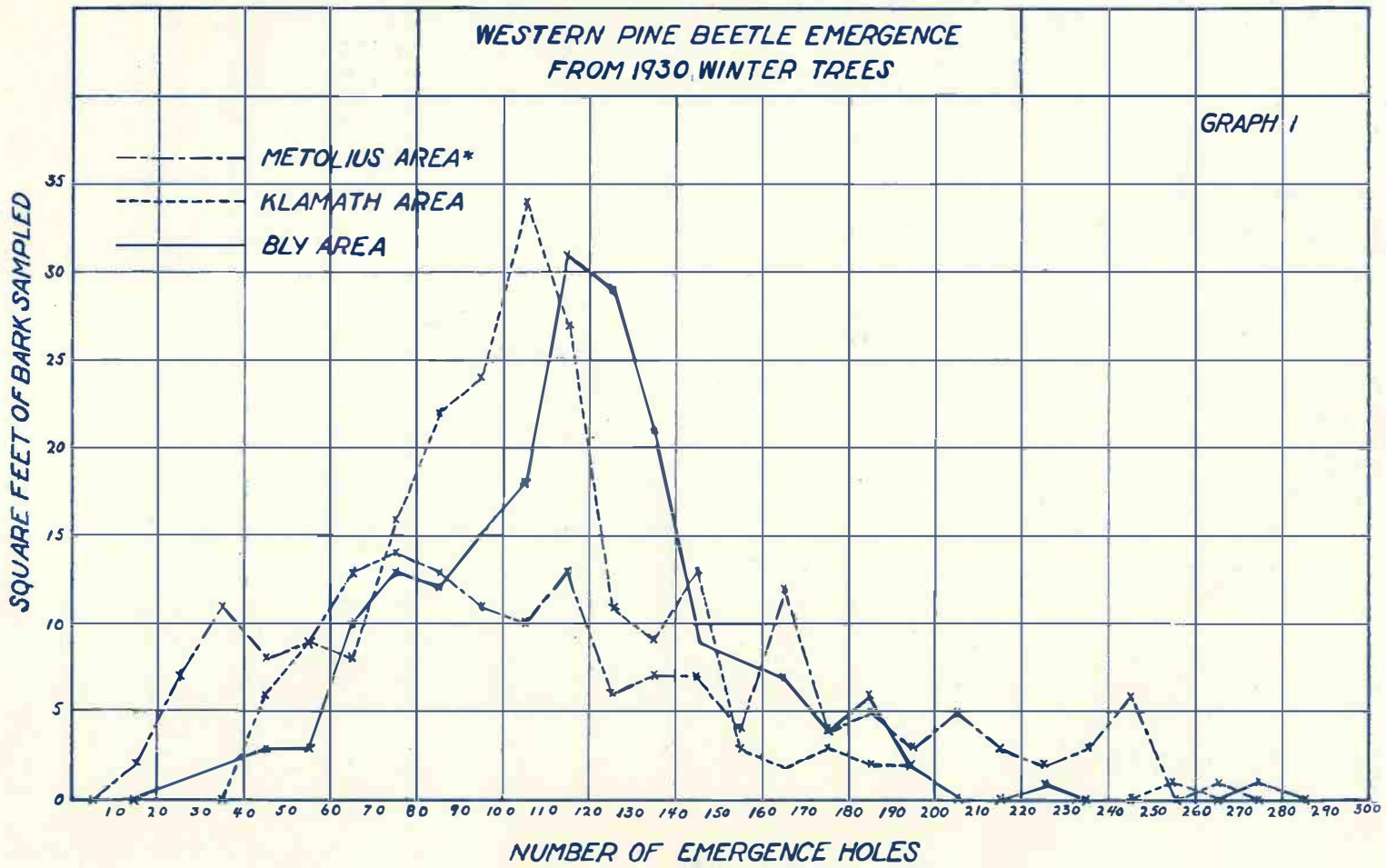
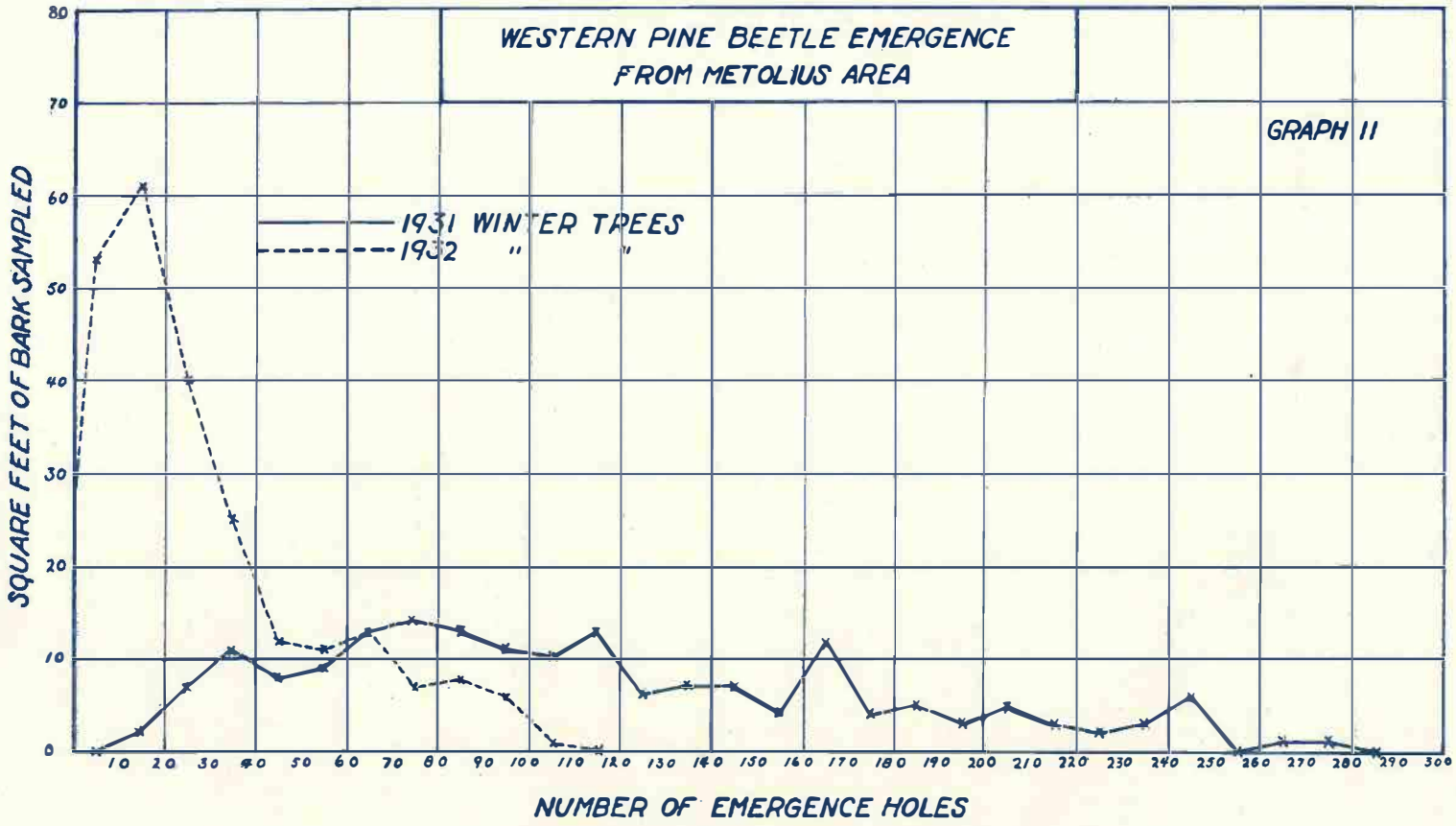
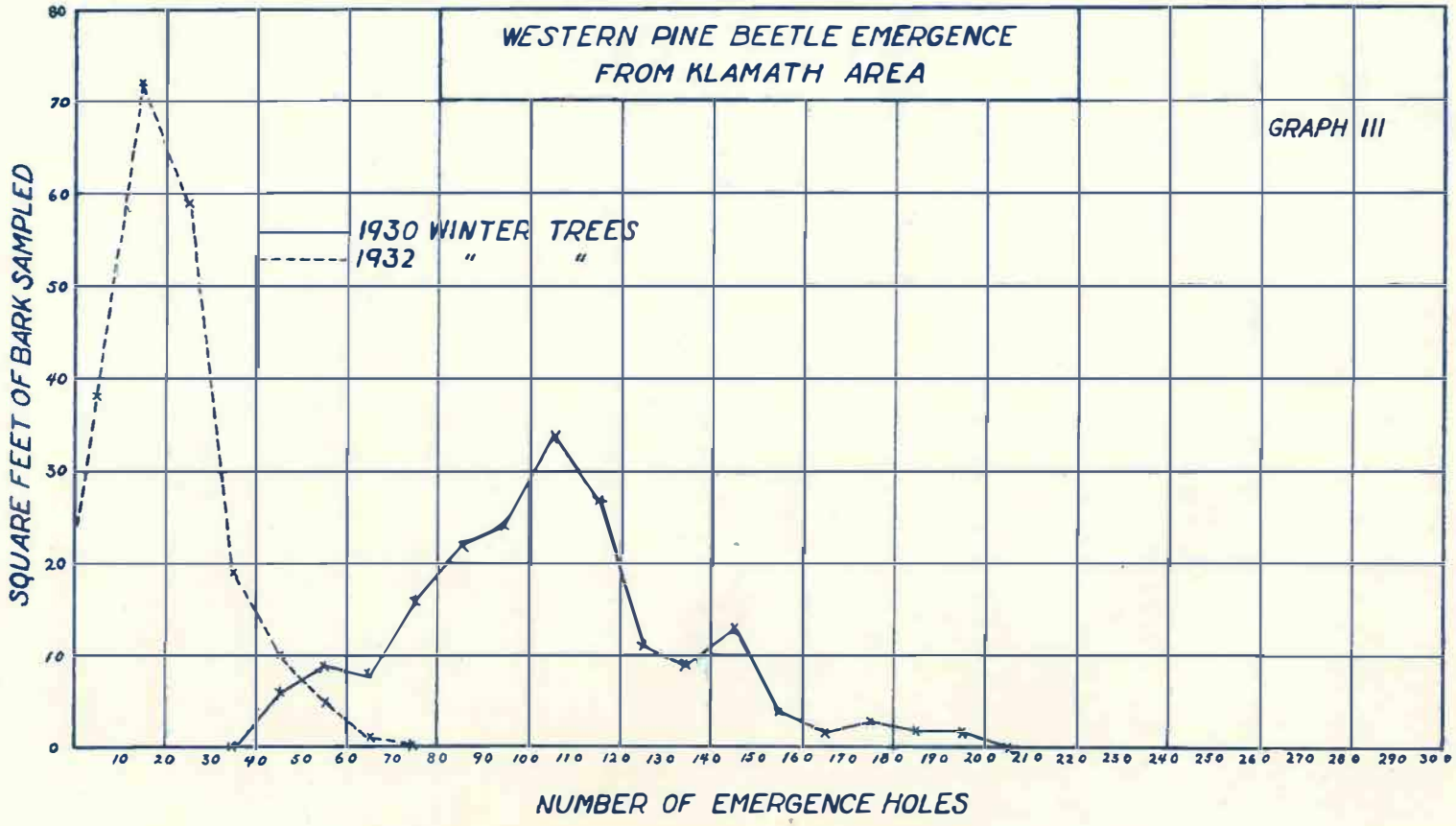
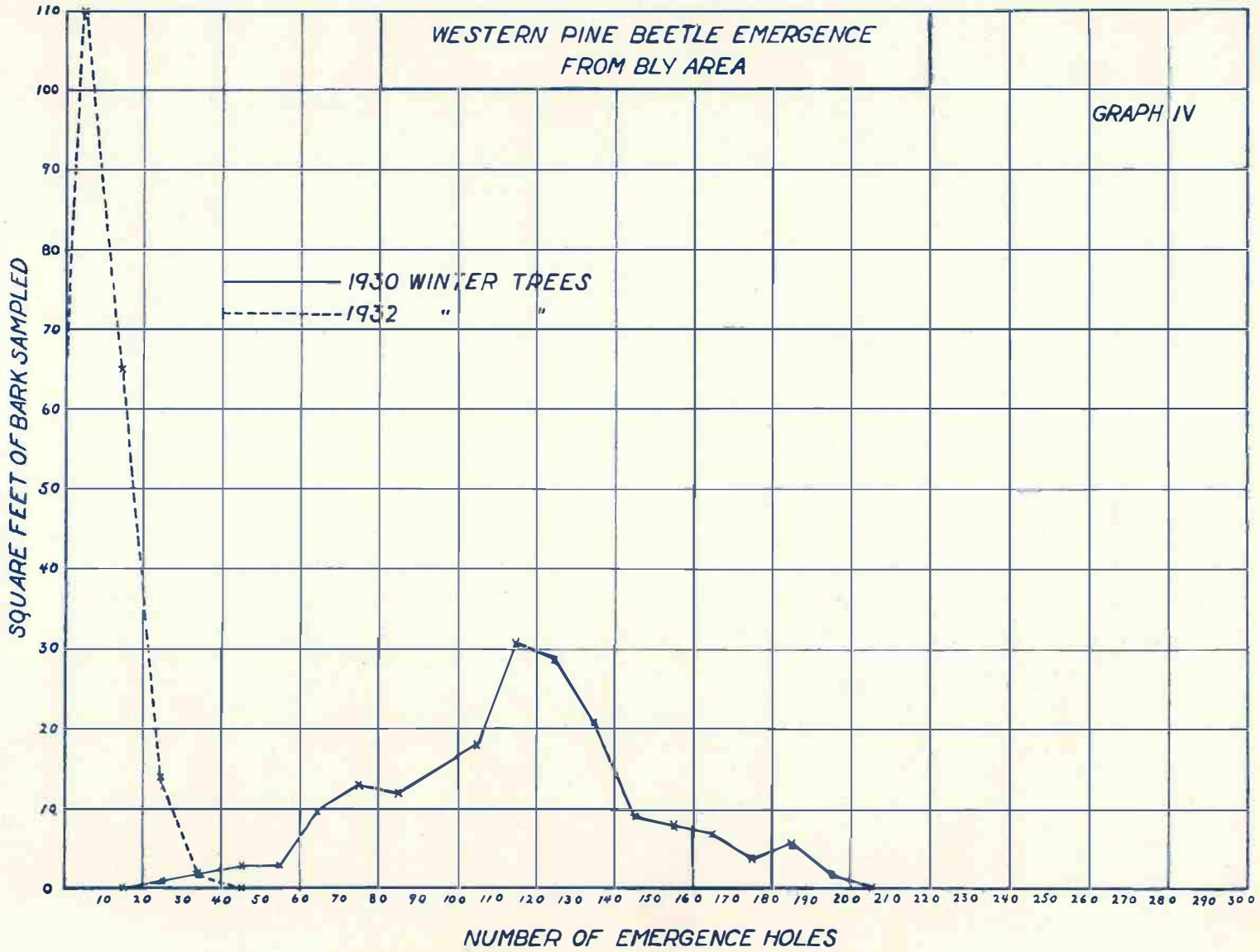

WESTERN PINE BEETLE EMERGENCE
FROM 1930 WINTER TREES
GRAPH 1
METOLIUS AREA*
KLAMATH AREA
BLY AREA
SQUARE FEET OF BARK SAMPLED
0
5
10
15
20
25
30
35
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
NUMBER OF EMERGENCE HOLES

* 1931


WESTERN PINE BEETLE EMERGENCE
FROM METOLIUS AREA
GRAPH II
1931 WINTER TREES
1932 " "
SQUARE FEET OF BARK SAMPLED
0
10
20
30
40
50
60
70
80
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
NUMBER OF EMERGENCE HOLES


WESTERN PINE BEETLE EMERGENCE
FROM KLAMATH AREA
GRAPH III
1930 WINTER TREES
1932 " "
SQUARE FEET OF BARK SAMPLED
NUMBER OF EMERGENCE HOLES
0
10
20
30
40
50
60
70
80
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300


WESTERN PINE BEETLE EMERGENCE
FROM BLY AREA
GRAPH IV
1930 WINTER TREES
1932 " "
SQUARE FEET OF BARK SAMPLED
NUMBER OF EMERGENCE HOLES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300